BLM LIBRARY
88076411

ANNUAL REPORT

# NITROGEN

By Raymond L. Cantrell

BLM LIBRARY

1990

U.S. DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

HD
9660
.N6
N58
1990

BLM Library
Denver Federal Center
Bldg. 50, OC-521
P.O. Box 25047
Denver, CO 80225

#1262339484
ID; 88076411
HD
9660
.N6
N58
1990

ANNUAL REPORT

# NITROGEN

MARCH 3, 1849

U.S.
DEPARTMENT
OF THE
INTERIOR

Manuel Lujan, Jr.
Secretary

BUREAU
OF
MINES

T S Ary
Director

October 1991

# Contents

- Domestic Data Coverage 1
- Background 2
  - Definitions, Grades, and Specifications 2
  - Technology 2
    - Mining 2
    - Processing 2
  - Economic Factors 3
- Annual Review 3
  - Legislation and Government Programs 3
  - Issues 4
  - Production 5
  - Consumption and Uses 7
  - Stocks 8
  - Transportation 8
  - Markets and Prices 9
  - Foreign Trade 9
  - World Review 10
    - Industry Structure 11
    - Capacity 11
  - Current Research 12
- Outlook 12

*COVER PHOTO:*
*The Mississippi Delta is blessed with rich soils and ideal climatic conditions for growing cotton. Cotton is a renewable resource strategic to our Nation's supply of natural textile fiber, vegetable oils, meals, and chemical derivatives.*
*(Photo is courtesy of Mississippi Chemical Corp., Yazoo City, MS.)*

# Tables

- Table 1.—Salient Ammonia Statistics 1
- Table 2.—Time-Price Relationships for Ammonia and Natural Gas 3
- Table 3.—Fixed Nitrogen Production in the United States 5
- Table 4.—Major Downstream Nitrogen Compounds Produced in the United States 5
- Table 5.—Domestic Producers of Anhydrous Ammonia in 1990 6
- Table 6.—Consumption Trends for Major Nitrogen Compounds Produced in the United States 8
- Table 7.—U.S. Nitrogen Fertilizer Consumption, by Product Type 8
- Table 8.—U.S. Producer Stocks of Fixed Nitrogen Compounds at Yearend 8
- Table 9.—Price Quotations for Major Nitrogen Compounds at Yearend 9
- Table 10.—U.S. Exports of Anhydrous Ammonia, by Country 10
- Table 11.—U.S. Imports of Anhydrous Ammonia, by Country 10
- Table 12.—U.S. Exports and Imports of Major Nitrogen Compounds in 1990 10
- Table 13.—World Anhydrous Ammonia Annual Production Capacity, December 31, 1990 13
- Table 14.—Ammonia: World Production, by Country 14
- Table 15.—World Anhydrous Ammonia Supply-Demand Relationships 15

*For comments or further information, please contact*
*The Branch of Industrial Minerals*
*The Division of Mineral Commodities*
*U.S. Bureau of Mines*
*2401 E St., NW, MS 5209*
*Washington, DC 20241-0001*
*Telephone: (202) 634-1190*
*Fax: (202) 634-4091*

# NITROGEN

## By Raymond L. Cantrell

**In June 1988, Mr. Cantrell entered public service with the U.S. Bureau of Mines in the capacity of physical scientist, chemical materials specialist. He was previously affiliated with W.R. Grace & Co., Hasbro Industries, and Columbia Nitrogen Corp. Domestic survey data were prepared by Tonya Hardin, mineral data assistant; and international data tables were prepared by Virginia Woodson, international data coordinator.**

Nitrogen is an absolute requirement for all life forms on Earth. The gas cycles between its inert diatomic form ($N_2$) in the atmosphere and chemically fixed forms on Earth, weaving an intricate balance with the carbon cycle that is driven by the photosynthesis processes of living plants. Plants absorb carbon dioxide from the atmosphere, synthesize carbohydrates and essential amino acids and proteins (nitrogen forms), and emit oxygen, all prerequisite to life. The microorganisms of the rhizosphere topsoil supply available mineral nitrogen to nonleguminous plants and biological nitrogen to leguminious (nitrogen fixing) plants for human and animal nutrition.

Elemental nitrogen gas and liquid ($N_2$), together with synthetic anhydrous ammonia ($NH_3$)—a derivative of atmospheric nitrogen and fossil fuels—form the base for an enormous global agricultural and industrial sector. Elemental nitrogen is used extensively by the electronics, metals, food, and aerospace industries because of its unique inert and cryogenic properties. Nitrogen contained in anhydrous ammonia and its downstream fertilizer derivatives provides more than 50% of the world's essential plant nutrient demand. In the industrial sector, anhydrous ammonia derivatives are important for the production of synthetic fibers, resins and polymers, explosives, animal feeds, and an enormous array of inorganic and organic compounds.

In 1990, U.S. elemental nitrogen sales amounted to an impressive $0.8 billion and were expected to rise to about $1.1 billion (38%) by 1994.[1]

The U.S. agricultural nitrogen and industrial chemical sectors also experienced a good year in 1990. Ammonia producers operated at near capacity (17 million tons), the nitrogen trade deficit declined 20% to 1.3 million tons N, and net cash farm income reached a record $59 billion. Natural gas feedstock for ammonia production was available at reasonable prices. Shipments of U.S. nitrogen fertilizer materials exceeded $4 billion.

Anhydrous ammonia facilities in 66 countries produced approximately 131 million short tons that was valued at about $13 billion. World ammonia production declined by a net 1.3 million tons in 1990 owing to economic pressures accompanying sweeping political reform in the Eastern bloc, together with the Persian Gulf crisis prompted by Iraq's invasion of Kuwait in early August. There was a significant runup in global fertilizer and petroleum prices during the fourth quarter of 1990 as a result of the Gulf crisis.

## DOMESTIC DATA COVERAGE

Industry statistics for anhydrous ammonia and derivative products were developed by the Bureau of the Census, U.S. Department of Commerce. Preliminary monthly data were published under

TABLE 1

### SALIENT AMMONIA STATISTICS[1]

(Thousand short tons of contained nitrogen unless otherwise specified)

| | 1986 | 1987 | 1988 | 1989 | 1990[p] |
|---|---|---|---|---|---|
| United States: | | | | | |
| Production | 11,909 | 13,232 | 13,827 | [r]13,449 | 13,940 |
| Exports | 531 | 848 | 642 | 381 | 531 |
| Imports for consumption | 2,048 | 2,357 | 3,032 | 3,154 | 2,947 |
| Consumption, apparent[2] | 13,714 | 15,193 | 16,250 | [r]16,306 | 16,413 |
| Stocks, Dec. 31: Producers' | 1,507 | 1,053 | 1,020 | 936 | 879 |
| Price per ton product, yearend, f.o.b. gulf coast[3] | $75 | $90 | $128 | $87 | $117 |
| Net import reliance[4] as a percent of apparent consumption | 13 | 13 | 15 | [r]18 | 15 |
| Natural gas price: Wellhead[5] | $1.94 | $1.67 | $1.69 | [r]$1.69 | $1.72 |
| World: | | | | | |
| Production | [r]100,389 | [r]103,198 | [r]109,448 | [r]109,142 | [e]108,056 |
| Trade[6] | 7,920 | 9,080 | 10,210 | 10,830 | [p]10,920 |

[e]Estimated. [p]Preliminary. [r]Revised.

[1] Synthetic anhydrous ammonia, calendar year data; excludes coke oven byproduct.

[2] Calculated from production plus imports minus exports plus or minus industry stock changes.

[3] Green Markets, Fertilizer Market Intelligence Weekly, McGraw-Hill, Inc.

[4] Defined as imports minus exports plus adjustments for industry stock changes.

[5] Monthly Energy Review, U.S. Department of Energy. Average annual cost at wellhead in dollars per thousand cubic feet.

[6] International Fertilizer Industry Association statistics—World Anhydrous Ammonia Trade.

product codes 28731, 28732, and 28742 in Current Industrial Reports (CIR), Fertilizer Materials, M28B. Final monthly data are subsequently published in a companion annual report MA28B. During 1990, the Bureau of the Census surveyed approximately 250 known producers of inorganic fertilizer materials. Production data are shown in table 1.

Statistics covering industrial gases were reported in the Bureau of the Census CIR publications M28C and MA28C, Industrial Gases.

## BACKGROUND

Nitrogen chemical matter developed as part of our solar system about 5 billion years ago, according to astrophysics. About 4 billion years ago, volcanic activity was believed to have belched gases from the bowels of primordial Earth, forming the nucleus for the nitrogen-rich atmosphere as we know it today. Nitrogen was discovered independently in 1772 by the Swedish druggist, Carl Scheele, and the Scotch botanist, Daniel Rutherford.[2]

Planet Earth is enveloped by an atmosphere dominated by nitrogen ($N_2$), oxygen ($O_2$), and water vapor ($H_2O$), above which lies a delicately thin layer of protective ozone ($O_3$) that screens harmful ultraviolet radiation. Trace gases in the atmosphere such as carbon dioxide ($CO_2$) absorb much more radiant energy than they release, providing the additional warmth necessary for our habitation of the planet.

The air we breathe consists of about 78% $N_2$ and about 21% $O_2$ by volume; argon makes up most of the remainder. Trace amounts of helium, hydrogen, krypton, neon, and xenon are natural atmospheric sources, together with the greenhouse gases—global warming gases—carbon dioxide ($CO_2$), methane ($CH_4$), and nitrous oxide ($N_2O$). Fossil fuel combustion has been responsible for a significant buildup in atmospheric $CO_2$ during the 20th century.

At the turn of the century, natural sources of nitrogen chemical materials supplied virtually all of the nutrient requirements for agricultural crop production. Mineralized organic soil nitrogen, domestic animal manures and byproducts, guano, seed meals, and coke oven ammonia predominated. The mineralized occurrences of sodium nitrate found in the Atacama Desert of northern Chile also provided strategic supplies of agricultural nitrogen to the global community.

In the late-1800's, agronomists warned that a global food crisis would materialize unless supplemental nitrogen forms could be found to increase crop production for the exploding world population. Scientific ingenuity prevailed, as four major industrial nitrogen fixation technologies evolved between 1900 and 1920: (1) the electric arc process, developed by Birkeland and Eyde in Norway, produced nitric oxide (NO) from atmospheric nitrogen and oxygen that was used to produce nitric acid ($HNO_3$); (2) the cyanamide process, discovered by Frank and Caro in Germany, synthesized calcium cyanamide ($CaCN_2$) from calcium carbide ($CaC_2$) and $N_2$; (3) the cyanide process, developed by Bucher of Brown University in Rhode Island, produced sodium cyanide (NaCN) from $N_2$ and sodium carbonate ($Na_2CO_3$) as an intermediate to ammonia production; and, (4) the ammonia process, developed by Haber and Bosch in Germany, reacted $N_2$ and hydrogen ($H_2$) under high temperatures and pressures in the presence of a catalyst to form ammonia ($NH_3$).

The Haber-Bosch process overshadowed all other industrial methods for producing nitrogen chemical materials and fostered today's mammoth ammonia-based nitrogen fertilizer and industrial sectors.

### Definitions, Grades, and Specifications[3]

At ordinary ambient temperature and pressure, anhydrous ammonia is a colorless gas with a very sharp, characteristic odor. Ammonia condenses to a liquid at minus 28° F. Anhydrous ammonia is not a poison and has no cumulative toxic effects on the human body. It, however, is corrosive and may cause minor lung, throat, mouth, nose, and eye irritation. When liquid anhydrous ammonia comes into direct contact with the skin, a severe burn may result. Anhydrous ammonia is not combustible except when its concentration in the air falls between 16% to 25% at temperatures in excess of 1,560° F.

Ammonia vapor becomes "life threatening" only when exposure levels reach 2,500 to 6,500 parts per million for up to 30 minutes or "rapidly fatal" if exposure levels reach 5,000- to 10,000 part per million concentrations for up to 30 minutes. Goggles, respirators, gloves, other protective body gear, and plenty of water—in cases of personal exposure or spills—should be readily available when working with ammonia. Steel is the only acceptable metal allowed in the process of transfer, storage, and transport of anhydrous ammonia.

### Technology

Elemental nitrogen is mined from the air by cryogenic separation and membrane technologies. In a typical air separation plant, liquefied air is separated into its individual components by fractional distillation. The resources of nitrogen in the air are virtually unlimited and renewable because of the continuous nitrogen cycle between fixed forms on Earth and atmospheric nitrogen.

***Mining.***—Mineralized occurrences of sodium nitrate ($NaNO_3$) and potassium nitrate ($KNO_3$) are mined in significant quantities in the Atacama Desert of northern Chile. The extremely arid nature of this region with its paucity of soil microorganisms creates an ideal environment for preserving the nitrate deposits that formed in Miocene times. The nitrate content of the deposits range from about 6.5% to 50%, with an estimated reserve base of about 2.5 billion tons.

Product grades of sodium nitrate and sodium nitrate-potassium nitrate mixtures are obtained through selective precipitation and filtering, followed by granulation. In 1990, Sociedad Quimica y Minera de Chile S.A. (SQM) produced more than 1 million tons of granular sodium nitrate and mixed potassium products for fertilizer and industrial use.[4] SQM's principal product line, in order of importance, included sodium nitrate (16% N) and homogeneous chemical mixtures of sodium nitrate and potassium nitrate containing 15% N and 14% potash ($K_2O$). Sodium nitrate was also blended with potash to produce a mixed fertilizer containing 13% N and 44% $K_2O$.

***Processing.***—Anhydrous ammonia is typically produced through a sequence of catalytically driven reactions involving the steam reforming of natural gas in the presence of air to produce hydrogen and nitrogen in the proper ratio to effect ammonia synthesis. The latest state-of-the-art plants operate at less than 25 million British thermal units (Btu) per ton, resulting in an energy efficiency of more than 70%.

Modern ammonia plants employ efficient centrifugal compressors for air and synthesis gas compression. Temperatures and pressures fluctuate throughout an ammonia plant depending on the process, but typically vary between 600° to 1,800° F and 500 to 3,000 pounds per square inch gauge, respectively. A nickel catalyst is used in the reformer and associated front-end sections of the plant, while an iron-promoted catalyst is used for ammonia synthesis.

Urea is formed when ammonia is reacted with byproduct carbon dioxide ($CO_2$) generated during ammonia synthesis. The materials are reacted under high pressure in a two-step reaction at about 400° F to first form ammonium carbamate, which then decomposes to urea ($NH_2CONH_2$).

Nitric acid is formed when ammonia is passed over a platinum-rhodium catalyst at about 1,700° F and 120 pounds per square inch gauge. As ammonia passes over the catalyst gauze, it reacts with oxygen to form nitric oxide (NO), which is converted to nitric acid by mixing with water in a countercurrent absorption tower. Ammonium nitrate, in turn, is formed by the simple acid-base reaction between ammonia and nitric acid.

### Economic Factors

The data of table 2 reflect long-term price trends for U.S. ammonia and natural gas over a period of 21 years (1970–90). The ratio of ammonia prices to natural gas feedstock prices provides a measure of ammonia's relative price sensitivity to changing feedstock costs. This relationship, however, does not give an accurate account of the impact of market forces and improvements in production efficiency on indicative profitability in the U.S. ammonia market. Between 1970 and the early-1980's, natural gas prices rose dramatically, and ammonia production costs became much more sensitive to feedstock costs. Feedstock costs as a percentage of total production costs rose precipitiously, from 45% in 1970 to 75% by 1982. Natural gas prices have declined since 1985, and feedstock costs now represent about 70% of total production costs.

The U.S. ammonia industry experienced record profitability during 1974–75 because of a tight global supply situation, in spite of the rising dependency on feedstock costs; a similar situation developed during 1979–81. Conversely, the U.S. ammonia industry suffered substantial losses in 1986–87 owing to a significant downturn in global agriculture. In 1990, the U.S. ammonia industry returned to respectable profit margins.

On April 3, 1990, the New York Mercantile Association (NYMEX) established natural gas futures trading in the United States. Natural gas futures trading was designed to allow suppliers, producers, and end users to shift or hedge price risks. NYMEX believed that natural gas futures contracts would provide the same liquidity, unambiguous price reference, and hedge against risk characterized by its successful petroleum contract system. Futures prices reflected price stability in the U.S. natural gas market for the coming year.

TABLE 2

### TIME-PRICE RELATIONSHIPS FOR AMMONIA AND NATURAL GAS

(Dollars per ton and dollars per million Btu)

| Year | Ammonia |  | Natural gas |  | Ammonia-natural gas ratio |
|---|---|---|---|---|---|
|  | Actual value[1] | Constant 1990 dollars | Actual value[2] | Constant 1990 dollars | Actual value[3] |
| 1970 | 34 | 106 | 0.17 | 0.53 | 200 |
| 1971 | 34 | 101 | .18 | .53 | 189 |
| 1972 | 35 | 99 | .19 | .54 | 184 |
| 1973 | 43 | 114 | .22 | .58 | 195 |
| 1974 | 93 | 226 | .30 | .73 | 310 |
| 1975 | 148 | 328 | .44 | .98 | 336 |
| 1976 | 107 | 223 | .58 | 1.21 | 184 |
| 1977 | 102 | 199 | .79 | 1.54 | 129 |
| 1978 | 102 | 186 | .91 | 1.66 | 112 |
| 1979 | 107 | 179 | 1.18 | 1.97 | 91 |
| 1980 | 130 | 199 | 1.59 | 2.44 | 82 |
| 1981 | 146 | 204 | 1.98 | 2.77 | 74 |
| 1982 | 141 | 185 | 2.46 | 3.23 | 57 |
| 1983 | 139 | 176 | 2.59 | 3.28 | 54 |
| 1984 | 152 | 186 | 2.66 | 3.25 | 57 |
| 1985 | 140 | 166 | 2.51 | 2.98 | 56 |
| 1986 | 102 | 118 | 1.94 | 2.24 | 53 |
| 1987 | 98 | 110 | 1.67 | 1.87 | 59 |
| 1988 | 105 | 114 | 1.69 | 1.83 | 62 |
| 1989 | 104 | 108 | [r]1.69 | 1.76 | 62 |
| 1990[p] | 106 | 106 | 1.72 | 1.72 | 62 |

[p]Preliminary. [r]Revised.

[1] Value of shipments, f.o.b. plant, in dollars per ton.

[2] Value at wellhead, in dollars per million Btu.

[3] Ratio of ammonia value to natural gas value.

Source: Council of Economic Advisors (1990 implicit price deflators for gross national product); 1982 = 100.

## ANNUAL REVIEW

### Legislation and Government Programs

The Food, Agriculture, Conservation, and Trade Act of 1990, Public Law 101-624, signed on November 28, 1990,[5] and called the "1990 farm bill," extended many of the highly successful program initiatives of the 1985 bill. It created the "triple base flexibility" initiative that gave farmers more freedom to make planting decisions.

Under triple base, farmers lost Government subsidizies on 15% of their base acreage but gained the flexibility to plant virtually any crop except fruits and vegetables on this land and still receive

Government price support loans. The triple base initiative provided the impetus for a $13 billion reduction in Government "entitlement" farm program spending over a 5-year period as prescribed by the Omnibus Budget Reconciliation Act of 1990 (Public Law 101-508), signed on November 5, 1990.[6]

Farmers were also given the opportunity to hedge an additional 10% of program acreage to alternate crops at the risk of lost deficiency payments. Target prices were frozen at 1990 levels. The target price—expected price for the crop—sets the upper limit for deficiency payments—the lower of the two values calculated between target prices and actual market prices or loan rates.

The 1990 farm bill was one of the most environmentally progressive farm bills ever signed. The Environmental Conservation Acreage Reserve Program (ECARP) broadened the 1985 Conservation Reserve Program (CRP) provisions to divert up to 1 million acres of cropland to "wetlands reserve" in adverse water-quality areas. Total ECARP program acreage was required to increase from the current 34 million acres to 40 to 45 million acres by 1995.

Other environmental programs adopted, subject to appropriations, included the Agricultural Water Quality Protection Program (AWQPP)—a 10-million-acre voluntary incentive program designed to promote the efficient use of crop nutrients and pesticides and ensure safe storage, mixing, and handling of agricultural chemicals and animal wastes—and the Environmental Easement Program (EEP)—designed to create easements for long-term protection of environmentally sensitive lands through an approved natural resource management plan.

Forestry provisions in the new farm bill supported the President's "America the Beautiful Initiative" that challenged Americans to plant 1 billion trees annually.

The Clean Air Act of 1990 (Public Law 101-549), signed on November 15, 1990,[7] was the most comprehensive air pollution legislation passed in our Nation's history. The massive clean air bill contained 11 titles that targeted 3 principal forms of pollution: acid rain, smog, and toxic air pollutants. In total, about 30 million tons per year of hazardous chemicals and noxious pollutants was to be removed from the air.

Provisions were also incorporated for Stratospheric Ozone Protection (title VI), "renewable biomass energy and energy conservation incentives" under title VIII, and Clean Air Research (title IX). The National Energy Strategy report was issued by the Department of Energy (DOE) in early 1991 to provide guidance in implementing the new clean air bill, pursuant to the President's directive of mid-1989.[8]

Acid rain is caused primarily by sulfur dioxide ($SO_2$) and nitrogen oxide (NOx) emissions from coal-fired electrical powerplants. Under title IV, $SO_2$ emissions were slated to decline 10 million tons from 1980 levels by the year 2000, and NOx emissions were to be cut by 2 million tons.

Smog results when motor vehicle tailpipe exhaust gases, NOx and volatile organic compounds (VOC's), react photochemically. According to recent estimates, motor vehicles nationwide are responsible for about 45% of NOx emissions and 34% of nonmethane VOC emissions. Motor vehicle emissions are also reported to cause about 70% of total carbon monoxide (CO) pollution and generate about 18% of the Nation's particulate emissions and 40% of the total lead pollution.[9]

Under title II, reductions in vehicular NOx and VOC emissions of 60% and 35%, respectively, will be required by 1996. CO emissions standards will also be effected at the same time. Tighter emissions standards for trucks and buses and reduced CO emissions during the cold starting of cars are also included.

To meet the objectives of title II, gasolines will be reformulated and oxygenated as prescribed in section 219. The 2%-by-weight minimum oxygen content requirement will likely be met by a methyl tertiary butyl ether (MTBE) additive—a methanol-butane derivative—and to a lesser extent by ethanol, formulated in a 10%-by-volume blend with gasoline to produce "gasohol." Ethyl tertiary butyl ether (ETBE), an ethanol derivative, may also become a significant oxygenated fuel additive. Tax incentives for ethanol production and blending were renewed in the 1990 Budget Reconciliation bill to encourage its use. Between 1994 and the year 2000, MTBE demand was projected to rise 175% to 5.5 billion gallons and ethanol to 2.5 billion gallons (67%).[10]

Under title II, section 241, provisions were made for "clean alternative fuels" motor vehicle fleets that would be designed to run on liquefied natural gas, methanol, ethanol, hydrogen, and electricity.

Toxic air pollutants are released into the air in significant quantities, about 1.3 million tons annually, during chemical manufacture, petroleum refining, mining and processing, and solid waste combustion. Under title III, a list of 190 hazardous chemicals and materials was established for regulation with the requirement that maximum achievable control technology (MACT) be applied to industries emitting major sources of air toxics. Title III contained provisions that would reduce toxic air emissions by more than 75%.

Several important industrial nitrogen-containing compounds were on the list, including acrylonitrile, aniline, caprolactam, ethyl carbamate (urethane), hydrazine, coke oven byproducts, and cyanides. Ammonia and its downstream fertilizer derivatives were excluded from the list.

### Issues

The U.S. Department of Commerce, Bureau of the Census, announced that publication of the strategic fertilizer and industrial chemical reports—CIR series M28A, M28B, and M28C—might be discontinued because of budget restrictions. After receiving a significant public response in favor of preserving the publications, the Bureau of the Census elected to publish the reports on a quarterly basis, effective January 1, 1991.[11]

After years of data gathering and analysis, the Environmental Protection Agency (EPA) released its National Drinking Water Well survey on November 13, 1990. The study, a survey of community and rural drinking water wells for pesticide and nitrate presence, found nitrate in amounts above EPA's 10 parts per million maximum in less than 3% of the wells.

The Fertilizer Institute (TFI) reported that EPA's study might surprise some environmental groups that sought sweeping reforms in farm practices to protect ground water. TFI referenced several States that had already conducted in-depth studies indicating that nitrate occurrence above a natural level was usually due to factors other than fertilizer use, either poorly constructed wells or other point sources.

EPA released the preliminary results of its 1989 Toxics Release Inventory

(TRI), which indicated that 22,650 industrial facilities released about 3 million tons of toxic chemicals into the Nation's environment. The report found that between 1987 and 1989, TRI chemicals decreased by a favorable 18%.

In 1989, a total of approximately 200,000 tons of ammonia was released into the air (61%) and water (6%), injected into underground wells (17%), delivered to municipal waste treatment plants (14%), and disposed of in landfills (2%).

Between 1987 and 1989, ammonia losses to the atmosphere declined by a favorable 18%, and discharges into rivers, lakes, streams, and other bodies of water declined 25%. Ammonia processed through municipal waste treatment plants rose 14%, and underground injection disposal methods increased 17%.

### Production

In 1990, the U.S. ammonia industry ran at an impressive 98% of rated capacity. Thirty-three firms in 23 States produced 17 million short tons of anhydrous ammonia (82.2% N) an increase of 4% over that of the prior year. Louisiana, Oklahoma, and Texas, in order of importance, provided about 60% of total U.S. production; the Midwest, South, and Southeast, 30%; and the Western States and Alaska, 10%. Anhydrous ammonia production was buoyed by a good crop year, a reduction in the trade deficit, field inventory drawdowns, and a tight global supply situtation that developed in the fall because of the Persian Gulf crisis and Eastern bloc restructuring. Natural gas feedstock was reasonably priced.

About 90% of U.S. ammonia production was for fertilizer products and about 10% went into industrial products. Major downstream ammonia fertilizer derivatives included urea (46% N), diammonium phosphate (18% N), ammonium nitrate (35% N), and ammonium sulfate (21% N). Important industrial chemical derivatives were urea, ammonium nitrate, nitric acid (22% N), acrylonitrile (26% N), and caprolactam (12% N).

Mississippi Chemical Corp. (MCC) was operating ammonia, nitric acid, ammonium nitrate, urea, and urea-ammonium nitrate (UAN) solutions plants at Yazoo City, MS, that provided nitrogen products to 10 principal States in the South, Southwest, and Midwest. MCC's featured product was AMTRATE, a superior ammonium nitrate prill containing

TABLE 3

## FIXED NITROGEN PRODUCTION IN THE UNITED STATES

(Thousand short tons of contained nitrogen)

| | 1986 | 1987 | 1988 | 1989 | 1990[p] |
|---|---|---|---|---|---|
| Anhydrous ammonia, synthetic:[1] | | | | | |
| Fertilizer | 10,852 | 12,019 | 12,566 | [r]12,183 | 12,677 |
| Nonfertilizer | 1,057 | 1,213 | 1,261 | [r]1,266 | 1,263 |
| Total | 11,909 | 13,232 | 13,827 | [r]13,449 | 13,940 |
| Byproduct ammonia, coke plants:[e] [2] | | | | | |
| Ammonium sulfate | 50 | 50 | 60 | 60 | 50 |
| Ammonia liquor | 4 | 5 | 5 | 6 | 5 |
| Total | 54 | 55 | 65 | 66 | 55 |
| Grand total | 11,963 | 13,287 | 13,892 | [r]13,515 | 13,995 |

[e] Estimated. [p] Preliminary. [r] Revised.

[1] Current Industrial Reports, MA28B and M28B, Bureau of the Census.

[2] Quarterly Coal Report, U.S. Department of Energy. Production (1985-90) based on reported coke production trend.

TABLE 4

## MAJOR DOWNSTREAM NITROGEN COMPOUNDS PRODUCED IN THE UNITED STATES[1]

(Thousand short tons)

| Compound | 1986 | 1987 | 1988 | 1989[r] | 1990[p] |
|---|---|---|---|---|---|
| Urea: | | | | | |
| Gross weight | 6,264 | 7,433 | 7,914 | 7,963 | 7,907 |
| Nitrogen content | 2,881 | 3,419 | 3,640 | 3,663 | 3,637 |
| Ammonium phosphates:[2] | | | | | |
| Gross weight | 11,001 | 13,352 | 15,121 | 16,341 | 16,590 |
| Nitrogen content | 1,861 | 2,296 | 2,591 | 2,769 | 2,801 |
| Ammonium nitrate: | | | | | |
| Gross weight | 6,091 | 6,547 | 7,504 | 7,871 | 7,106 |
| Nitrogen content | 2,132 | 2,291 | 2,626 | 2,755 | 2,487 |
| Ammonium sulfate:[3] | | | | | |
| Gross weight | 2,080 | 2,189 | 2,333 | 2,347 | 2,495 |
| Nitrogen content | 437 | 460 | 490 | 493 | 524 |
| Nitric acid, direct use:[4] | | | | | |
| Gross weight | 1,939 | 2,069 | 2,082 | 2,151 | 2,152 |
| Nitrogen content | 431 | 460 | 463 | 478 | 478 |
| Acrylonitrile: | | | | | |
| Gross weight | 1,157 | 1,275 | 1,288 | 1,304 | 1,514 |
| Nitrogen content | 305 | 337 | 340 | 344 | 400 |
| Caprolactam: | | | | | |
| Gross weight | 425 | 580 | 631 | 656 | 690 |
| Nitrogen content | 53 | 72 | 78 | 81 | 86 |
| Total: | | | | | |
| Gross weight | 28,957 | 33,445 | 36,873 | 38,633 | 38,454 |
| Nitrogen content | 8,100 | 9,335 | 10,228 | 10,583 | 10,413 |

[p] Preliminary. [r] Revised.

[1] Ranked in relative order of importance.

[2] Diammonium phosphate (DAP), monoammonium phosphate (MAP), and other ammonium phosphates.

[3] Excludes coke plant ammonium sulfate.

[4] Gross nitric acid production adjusted for use in production of ammonium nitrate.

Sources: Bureau of the Census and International Trade Commission.

34% available nitrogen. AMTRATE prills remain free-flowing even when handled under hot, humid conditions owing to MCC's recently developed proprietary technology. The construction of a new 200,000-ton-per-year nitric acid plant scheduled on-stream in late-1992 will increase AMTRATE output. N-sol 32, a UAN solution containing 32% N, was also a featured product. MCC holds a 50% interest in Triad Chemical, a major urea production complex at Donaldsonville, LA.

In February, Freeport-McMoRan Resource Partners (FRP) sold its Agrico Div. nitrogen fertilizer facilities at Verdigris, OK, and Blytheville, AR, and certain fertilizer terminal facilities for $230 million.[12] Agricultural Minerals Corp. (AMC) was formed to purchase the plants in a leveraged buyout. AMC assumed control of the Verdigris, OK, and Blytheville, AR, plants effective March 1 and planned to establish headquarters in Tulsa, OK.

Ammonia, urea, and UAN solutions are the primary products produced by AMC, along with the highly efficient slow-release Super N fertilizers containing dicyandiamide. AMC ranked second in U.S. UAN capacity, fourth in ammonia capacity, and fifth in terms of urea capacity.

In June, Freeport's Agrico Div. sold its 25% interest in Namhae Chemical, a nitrogen and phosphate fertilizer facility in the Republic of Korea, for $80 million.[13]

In October, the W. R. Grace Agricultural Chemicals Group in Memphis, TN, signed a letter of intent to sell ammonia interests at Point Lisas, Trinidad, to Norsk Hydro a.s. of Norway. Included in the sale were Grace's wholly owned Federation Chemicals Ltd. ammonia plant (255,000 annual tons) and a 49% share in Trinidad Nitrogen Co. Ltd., a joint venture with the Government of Trinidad and Tobago in two ammonia plants (Tringen I & II), having a combined annual capacity of 920,000 tons. The sale was finalized in late December.

Grace also transferred ownership of its U.S.-based marketing operations and shipping interests that were linked to the output of the Trinidad facilities. Hydro Agri Ammonia, Inc. (HAAI), a U.S. affiliate of Norsk Hydro, was established in Tampa, FL, for this purpose. HAAI was staffed by key personnel from the former Grace marketing team in Memphis, TN.

TABLE 5

## DOMESTIC PRODUCERS OF ANHYDROUS AMMONIA IN 1990

(Thousand short tons per year of ammonia)

| Company | Location | Capacity[1] |
|---|---|---|
| Freeport-McMoRan (Agrico) | Donaldsonville, LA | [r]500 |
| Agricultural Minerals Corp.[2] | Blytheville, AR | [r]390 |
| Do. | Verdigris, OK | 950 |
| Air Products and Chemicals Inc. | New Orleans, LA[3] | 290 |
| Do. | Pace Junction, FL | 100 |
| Allied Chemical Corp. | Hopewell, VA[3] | [r]410 |
| American Cyanamid Co. | Fortier, LA[3] | 425 |
| Arcadian Corp.[4] | Augusta, GA | 545 |
| Do. | Clinton, IA | 256 |
| Do. | Geismar, LA | 352 |
| Do. | Lake Charles, LA | 460 |
| Do. | LaPlatte, NE | 190 |
| Do. | Woodstock, TN | 340 |
| Nitrogen Products, Inc.[5] | Helena, AR[3] | 210 |
| Borden Chemical Co. | Geismar, LA | 400 |
| Carbonaire Co. Inc. | Palmerton, PA | 35 |
| CF Industries Inc. | Donaldsonville, LA | [r]1,740 |
| Do. | Terre Haute, IN[6] | — |
| Chevron Chemical Co. | El Segundo, CA | 20 |
| Do. | Pascagoula, MS[7] | — |
| Do. | St. Helens, OR | 80 |
| Do. | Finley, WA | 140 |
| Coastal Chem, Inc.[8] | Cheyenne, WY | [r]170 |
| Cominco American Inc. | Borger, TX[3] | [r]400 |
| E.I. du Pont de Nemours & Co. Inc. | Beaumont, TX | [r]490 |
| Farmland Industries Inc. | Beatrice, NE | 237 |
| Do. | Dodge City, KS | 210 |
| Do. | Enid, OK | 840 |
| Do. | Fort Dodge, IA | 210 |
| Do. | Hastings, NE | [9]140 |
| Do. | Lawrence, KS | 400 |
| Do. | Pollock, LA[3] | 420 |
| First Mississippi Corp. (Ampro) | Donaldsonville, LA[3] | [r]450 |
| Green Valley Chemical Corp. | Creston, IA | 35 |
| IMC Fertilizer Group, Inc. | Sterlington LA | 1,050 |
| Jupiter Chemicals | West Lake, LA | 30 |
| LaRoche Industries Inc. | Cherokee, AL | 175 |
| Mississippi Chemical Corp. | Yazoo City, MS[3] | [r]500 |
| Monsanto Co. | Luling, LA[5] | 460 |
| Occidental Chemical Corp. | Tacoma, WA | 28 |
| Pennwalt Chemical Co. | Portland, OR | 8 |
| Phoenix Chemical Co.[10] | East Dubuque, IL | 238 |
| PPG Industries Inc. | Natrium, WV | 50 |
| J. R. Simplot Co. | Pocatello, ID | 108 |
| Sohio Chemical Co. (BP Intl Ltd) | Lima, OH[3] | 530 |
| Tennessee Valley Authority[11] | Muscle Shoals, AL | — |
| Terra International, Inc. | Port Neal, IA | 230 |
| Do. (Oklahoma Nitrogen) | Woodward, OK | 450 |
| Triad Chemical Co.[12] | Donaldsonville, LA[3] | [r]420 |

See footnotes at end of table.

TABLE 5—Continued

## DOMESTIC PRODUCERS OF ANHYDROUS AMMONIA IN 1990

(Thousand short tons per year of ammonia)

| Company | Location | Capacity[1] |
|---|---|---|
| Union Chemical Co. (Unocal) | Kenai, AK | 1,200 |
| Do. | Brea, CA[11] | — |
| Wil-Grow Fertilizer Co.[10] | Pryor, OK | 94 |
| Total | | [r]17,406 |

[r] Revised.

[1] Engineering design capacity adjusted for 340 days per year of effective production capability.

[2] Plants purchased from Freeport-McMoRan Feb. 28, 1990.

[3] Revamp and/or retrofit.

[4] Plants purchased late May through early Nov. 1989 by Fertilizer Industries, holding company for the Sterling Group and Unicorn Venture Funds.

[5] Closed Mar. 1989; operated intermittently in 1990 under new ownership.

[6] Plant dismantled (150,000 annual tons).

[7] Large 530,000-ton-per-year plant idle for more than 3 years will reportedly be dismantled.

[8] Wycon Chemical Co. assumed parent company's name, midyear 1989.

[9] Plant idle.

[10] Former N-Ren Corp. plants acquired by Great American Management and Investment, Aug. 1987.

[11] Plant closed midyear 1989.

[12] Joint venture between First Mississippi Corp. and Mississippi Chemical Corp.

Sources: Economics and Marketing Research Section, Tennessee Valley Authority. North American Fertilizer Capacity, Ammonia. Muscle Shoals, AL, Jan. 1991, and U.S. Bureau of Mines.

In late 1990, Chevron Chemical Co. announced plans to divest its fertilizer divisions, including active nitrogen production facilities in California, Oregon, and Washington State. Industry sources reported that Chevron's idle ammonia plant at Pascagoula, MS, (530,000 annual tons) would be dismantled and moved to Pakistan. A 400,000-ton-per-year diammonium phosphate (DAP) complex brought on-stream at Rock Springs, WY, in mid-1986 was also for sale.

Cargill Fertilizer of Minneapolis, MN, was building a C$430 million nitrogen fertilizer complex—the Saferco project—in Belle Plaine, Saskatchewan, through a joint venture between its Canadian subsidiary, Cargill Ltd., and the Crown Investments Corp. of the Province of Sasketchewan. Construction was 9% complete by yearend.[14] The plant was scheduled for completion in the fall of 1992 and was designed to produce 560,000 tons per year of ammonia and 750,000 tons per year of urea.

CF Industries was planning to expand urea and nitric acid capacity at its Donaldsonville, LA, nitrogen fertilizer complex. CF's Donaldsonville ammonia plants were capable of operating at 2 million tons per year, 120% of design capacity, because of recent revamp and retrofit initiatives. The planned expansions would lead to further improvements in the cooperative's competitive economics.

Coastal Chem, Inc. planned a 175,000-ton-per-year ammonia expansion by late 1992 at Cheyenne, WY, based on the reconstruction of a plant to be moved from Arcadian's Augusta, GA, complex. Coastal was constructing a 130,000-ton-per-year nitric acid plant at Elko, WY, that would be used to produce ammonium nitrate-base explosives. BP Chemicals announced a $17 million 90,000-ton-per-year nitric acid replacement/expansion at Lima, OH, that was scheduled on-stream in late 1992.

The former Big River ammonia complex at Helena, AR, was purchased by an investment consortium in bankruptcy proceedings during 1989 and renamed Five Rivers. The plant was subsequently closed in mid-1990 owing to a lack of reliable power sources and equipment failures. Ownership was transferred to the original lending institution, the Dutch-owned bank NMB, which contracted with the Royster Co. to operate a new enterprise called Nitrogen Products, Inc. A 210,000-ton-per-year ammonia plant was to be revamped and on-stream by late December 1990.

In August, Diamond Shamrock acquired the Center Plains ammonia facility at Dumas, TX, in bankruptcy proceedings through a repurchase agreement and planned to reactivate one of the two 80,000-ton-per-year plants on-site in early 1991.

## Consumption and Uses

Fertilizer materials accounted for about 80% of domestic ammonia conversion disappearance, and about 20% went into industrial applications.

Urea and ammonium nitrate, in solid and liquid form, found extensive use in both the fertilizer and industrial sectors. UAN solution fertilizers that contain 28% to 32% N were growing in popularity because of their safe handling and storage characteristics and ease of application. In the industrial sector, urea was used in the production of synthetic fibers, resins, and polymers and as a protein supplement in ruminate animal feeds. Ammonium nitrate fuel oil explosives (ANFO) dominated the industrial explosives sector. Nitric acid was used in chemical synthesis and in metal treatment. Acrylonitrile and caprolactam found respective use in the production of acrylic and nylon fibers, resins, and plastics.

Other uses for ammonia and ammonia-base compounds were for speciality horticultural and lawn and garden fertilizers, home and industial cleaners, and as a propellant in vehicular air bags. Ammonia and urea were also becoming popular low-cost agents that significantly reduced NOx atmospheric emissions when injected into combustion gas streams.[15]

In 1990, ammonia and ammonia derivatives accounted for 54% of the 20.6-million-ton primary fertilizer nutrient market in the United States. The ratio of nitrogen nutrient consumption to phosphate and potash fertilizer nutrient consumption was 2.5:1 and 2.1:1, respectively.

U.S. nitrogen fertilizer consumption reached 11.1 million tons N in 1990, an increase of 5% over that of the prior year. Single-nutrient compounds, led by direct application ammonia, UAN solutions, and ammonium nitrate, in order of importance, provided 80% of the total. Urea and nitrogen solutions were up by more than 10% each, while direct application ammonia remained static.

The six States that comprise the Midwest Corn Belt—Illinois, Indiana, Iowa, Missouri, Nebraska, and Ohio—together with Minnesota, consumed 4.6 million tons N, 41% of the U.S. total. Texas, Kansas, California, and Oklahoma, in order of importance, accounted for 2.2 million tons N, 20% of the total.

U.S. net cash farm income rose 8% to a record $59 million in 1990. Planted crop acreage approximated 327 million

TABLE 6

## CONSUMPTION TRENDS FOR MAJOR NITROGEN COMPOUNDS PRODUCED IN THE UNITED STATES[1]

(Thousand short tons of contained nitrogen)

| | 1986 | 1987 | 1988 | 1989[r] | 1990[p] |
|---|---|---|---|---|---|
| Fertilizer materials: | | | | | |
| Urea: | | | | | |
| Solid | 1,529 | 1,904 | 2,028 | 1,999 | 2,064 |
| Solution | 1,033 | 1,137 | 1,201 | 1,232 | 1,164 |
| Total | 2,562 | 3,041 | 3,229 | 3,231 | 3,228 |
| Ammonium phosphates[2] | 1,861 | 2,296 | 2,591 | 2,769 | 2,801 |
| Ammonium nitrate: | | | | | |
| Solid | 623 | 626 | 776 | 793 | 767 |
| Solution | 963 | 1,012 | 1,193 | 1,231 | 1,144 |
| Other[3] | 43 | 53 | 10 | 46 | -68 |
| Total | 1,629 | 1,691 | 1,979 | 2,070 | 1,843 |
| Ammonium sulfate: | | | | | |
| Synthetic and byproduct | 437 | 460 | 490 | 493 | 524 |
| Coke oven byproduct[e] | 47 | 51 | 59 | 60 | 53 |
| Total | 484 | 511 | 549 | 553 | 577 |
| Total fertilizer | 6,536 | 7,539 | 8,348 | 8,623 | 8,449 |
| Nonfertilizer materials: | | | | | |
| Urea:[2] | | | | | |
| Feed | 107 | 142 | 171 | 193 | 81 |
| Industrial | 212 | 237 | 241 | 239 | 328 |
| Total | 319 | 379 | 412 | 432 | 409 |
| Ammonium nitrate[2] | 503 | 600 | 647 | 685 | 645 |
| Nitric acid | 431 | 460 | 463 | 478 | 478 |
| Acrylonitrile | 305 | 337 | 340 | 344 | 400 |
| Caprolactam | 53 | 72 | 78 | 81 | 86 |
| Total nonfertilizer | 1,611 | 1,848 | 1,940 | 2,020 | 2,018 |
| Grand total[4] | 8,147 | 9,386 | 10,287 | 10,643 | 10,466 |

[e]Estimated. [p]Preliminary. [r]Revised.

[1] Ranked in relative order of importance.

[2] Solid and solution.

[3] Unaccounted distribution.

[4] Data may not add to totals shown because of independent rounding.

Sources: Current Industrial Reports, MA28B and M28B, Bureau of the Census, and International Trade Commission.

TABLE 7

## U.S. NITROGEN FERTILIZER CONSUMPTION, BY PRODUCT TYPE[1]

(Thousand short tons nitrogen)

| Product type[2] | 1989[r] | 1990[p] |
|---|---|---|
| Single-nutrient: | | |
| Anhydrous ammonia | 3,792 | 3,800 |
| Nitrogen solutions[3] | 2,032 | 2,267 |
| Urea | 1,552 | 1,715 |
| Ammonium nitrate | 644 | 603 |
| Ammonium sulfate | 172 | 184 |
| Aqua ammonia | 100 | 82 |
| Other[4] | 137 | 177 |
| Total | 8,429 | 8,828 |
| Multiple-nutrient:[5] | 2,164 | 2,248 |
| Grand total | 10,593 | 11,076 |

[p]Preliminary. [r]Revised.

[1] Fertilizer years ending June 30.

[2] Ranked in relative order of importance by product type.

[3] Principally urea-ammonium nitrate (UAN) solutions.

[4] Includes other single-nutrient nitrogen materials and all natural organics.

[5] Various combinations of nitrogen (N), phosphate (P), and potassium (K): N-P-K, N-P, and N-K.

Source: Economics and Marketing Research Section, Tennessee Valley Authority. Commercial Fertilizers, Dec. 1990.

TABLE 8

## U.S. PRODUCER STOCKS OF FIXED NITROGEN COMPOUNDS AT YEAREND[1]

(Thousand short tons nitrogen)

| Material[2] | 1989 | 1990[p] |
|---|---|---|
| Ammonia | 936 | 879 |
| Nitrogen solutions[3] | 442 | 314 |
| Urea | 171 | 201 |
| Ammonium phosphates[4] | 138 | 105 |
| Ammonium sulfate | 53 | 52 |
| Ammonium nitrate | 64 | 49 |
| Total | 1,804 | 1,600 |

[p]Preliminary.

[1] Calendar year ending Dec. 31.

[2] Ranked in relative order of importance.

[3] Urea-ammonium nitrate and ammoniacal solutions.

[4] Diammonium, monoammonium, and other ammonium phosphates.

Source: Current Industrial Reports, M28B, Bureau of the Census.

acres, and another 60 million acres was idled by crop programs and the CRP.

### Stocks

U.S. nitrogen producer stocks declined to a level of 1.6 million tons N and stood 11% below 1989 levels at yearend. Field inventories were also believed to have declined because of favorable domestic nitrogen fertilizer consumption and trade.

### Transportation

In late December 1990, the Research and Special Programs Administration (RSPA) of the U.S. Department of Transportation (DOT) ruled that anhydrous ammonia should not be reclassified as a poisionous gas for the purposes of domestic transportation as previously proposed.[16] The RSPA ruled that classifying anhydrous ammonia as a nonflammable gas linked to the requirement of an "inhalation hazard label" would provide adequate hazard communication at substantially less cost and disruption to the agricultural and industrial users of the material. RSPA officially classified anhydrous ammonia a Division 2.2 nonflammable, nonpoisonous compressed gas for domestic shipments. A 5-year period was to be allowed for compliance.

International shipments, however, were classified as a Division 2.3 "poison gas" consistent with United Nation regulations. International shippers were required to comply under the new regulations by January 1, 1991. Because of the documented inhalation hazards of anhydrous ammonia when released in large quantities, RSPA was also requiring the words "INHALATION HAZARD" on packages and shipping papers, in addition to other current hazard communications requirements.

Ammonia was transported by refrigerated barge, rail, pipeline, and truck. Mapco Ammonia Pipeline Inc. was operating Mapco Ammonia Pipeline and its sister company, Mid-America Pipeline, along a 1,098-mile corridor that extended in a northeasterly direction from Borger, TX, in northern Texas, to Mankato, MN, in southern Minnesota. Mapco built the first leg of the pipeline in 1968-69 and, by 1978, had added six extensions. About 500,000 tons of ammonia storage capacity was located along the pipeline. Mapco Ammonia Pipeline neither produced nor marketed ammonia independently, but transported ammonia on behalf of five shippers. Competition from the rail and truck transportation sectors was minimized because areas served by Mapco Ammonia Pipeline did not have river access. Mid-America Pipeline had more than 400 shippers and competed with the other transportation sectors.[17]

Koch Industries was operating the Gulf Central Pipeline built in 1969 that extended about 1,900 miles from the Gulf of Mexico into the Midwest, as far north as Iowa. Koch Nitrogen, a subsidiary, purchased four Midwest ammonia terminals from ConAgra Fertilizer in 1990 having a combined capacity of 150,000 tons.

In October, the Interstate Commerce Commission (ICC) replaced the Federal Energy Regulatory Commission (FERC) as the Federal agency responsible for ammonia pipeline regulation. FERC had been responsible for ammonia pipeline regulation since 1977, when ICC transferred power of control under the Department of Energy Act. Actions on complaints that had been previously filed with FERC against ammonia pipelines for alleged excessive rate charges were delayed because of the transfer after the U.S. Court of Appeals ruled in favor of ICC control.

## Markets and Prices

Anhydrous ammonia prices continued an upward trend that had developed in the fall of 1989 because of strong domestic fertilizer movement and averaged $93 per ton, f.o.b. barge, New Orleans, for the first quarter. Urea followed a similiar trend, with granular product averaging $122 per ton, f.o.b. U.S. gulf coast. Anhydrous ammonia and urea prices fell during the second quarter and into the third quarter.

A dramatic rise in nitrogen fertilizer prices was precipitated following Iraq's invasion of Kuwait in early August. Anhydrous ammonia prices, f.o.b. barge, New Orleans, jumped 44% between July and December and sold for $117 per ton at yearend. Granular urea prices on the U.S. gulf coast rose about 26% and closed the year at $156 per ton. At yearend, prices for all major nitrogen fertilizers were up substantially relative to those of the prior year.

## Foreign Trade

Effective January 1, 1990, the Bureau of the Census reinstated anhydrous ammonia export and import tonnage data that had been suppressed in total during calendar year 1989. U.S.S.R. anhydrous ammonia import tonnage data, however, continued to be withheld from the public domain because of a previous ruling that determined Occidental Petroleum to be the proprietary U.S. agent.

In 1990, the U.S. ammonia trade deficit was 2.9 million product tons, about 13% favorable to the record 3.4 million ton deficit established in 1989. The average c.i.f. price of ammonia landed in the U.S. in 1990 was about $100 per ton. Canada, Trinidad and Tobago, the U.S.S.R., and Mexico, in order of importance, accounted for 97% of total U.S. anhydrous ammonia imports.

The total U.S. converted nitrogen trade deficit was 1.3 million tons N in 1990, 0.3 million tons (19%) favorable to the 1.6-million-ton deficit of 1989. Anhydrous ammonia (2.4 million ton N deficit) and urea (0.5 million ton N deficit) were the predominate trade deficit materials. In contrast, diammonium phosphate generated 1.5 million tons of positive N net trade.

The United States imported 2.1 million product tons of urea from 20 countries in 1990 that was valued at $251 million ($122 per ton c.i.f.). Canada provided 65% of the total, while Mexico, Trinidad, and Venezuela—in aggregrate—accounted for another 18%. Bulgaria, the Federal Republic of Germany, and Yugoslavia shipped an aggregrate total of 8% (157,000 tons), but International Trade Commission (ITC) antidumping provisions sheltered the domestic industry from U.S.S.R., the Federal Republic of

TABLE 9

### PRICE QUOTATIONS FOR MAJOR NITROGEN COMPOUNDS AT YEAREND

(Per short ton product)

| Compound | 1989 | 1990 |
|---|---|---|
| Ammonium nitrate: f.o.b. Corn Belt[1] | $105–$115 | $120–$125 |
| Ammonium sulfate: f.o.b. Corn Belt[1] | 100– 120 | 120– 130 |
| Anhydrous ammonia: | | |
| F.o.b Corn Belt | 110– 115 | 140– 145 |
| F.o.b. gulf coast[2] | 86– 88 | 115– 118 |
| Diammonium phosphate: F.o.b. central Florida | 125– 126 | 145– 148 |
| Nitrogen solutions (28% to 32%): | | |
| F.o.b. South Central[3] | 84– 98 | 95– 99 |
| Urea: | | |
| F.o.b. Corn Belt, prilled | 110– 120 | 155– 165 |
| F.o.b. gulf coast, granular[2] | 115– 117 | 155– 156 |
| F.o.b. gulf coast, prilled[2] | 98– 105 | 142– 145 |

[1] Illinois, Indiana, Iowa, Missouri, Nebraska, and Ohio.

[2] Barge, New Orleans.

[3] Alabama, Arkansas, Louisiana, Mississippi, Kentucky, Tennessee, and Texas.

Source: Green Markets, Fertilizer Market Intelligence Weekly, Dec. 25, 1989, and Dec. 24, 1990.

TABLE 10

### U.S. EXPORTS OF ANHYDROUS AMMONIA, BY COUNTRY

(Thousand short tons ammonia)[1]

| Country[2] | 1989 | 1990[p] |
|---|---|---|
| Korea, Republic of | 171 | 300 |
| South Africa, Republic of | 160 | 178 |
| Belgium | 29 | 101 |
| Denmark | 23 | — |
| France | 22 | 9 |
| Netherlands | — | 16 |
| Norway | — | 22 |
| Japan | 23 | — |
| Canada | 8 | 14 |
| Other[3] | 27 | 6 |
| Total | 463 | 646 |

[p] Preliminary.

[1] Value data suppressed by Bureau of the Census.

[2] Ranked in relative order of importance.

[3] Twenty-seven countries; principally Brazil, Costa Rica, El Salvador, Mauritius, Morocco, Trinidad, Spain, Taiwan, Tunisia, and Venezuela.

Sources: Bureau of the Census, The Fertilizer Institute (1989); Bureau of the Census (1990).

TABLE 11

### U.S. IMPORTS OF ANHYDROUS AMMONIA BY COUNTRY

(Thousand short tons ammonia)[1]

| Country | 1989 | | 1990[e p] | |
|---|---|---|---|---|
| | Gross weight | Value[2] (thousands) | Gross weight | Value[2] (thousands) |
| Canada[3] | [3]1,428 | [3,4]$136,308 | 1,220 | $122,525 |
| Trinidad and Tobago | 795– 980 | 92,270 | 882 | 88,841 |
| U.S.S.R. | 886– 898 | 84,028 | [5]875 | 84,123 |
| Mexico | 253– 268 | 22,830 | 505 | 52,242 |
| Venezuela | 31– 57 | 3,578 | 61 | 5,786 |
| Kuwait | 99– 133 | 14,644 | 34 | 2,868 |
| Saudi Arabia | 61– 75 | 7,166 | — | — |
| Bahrain | 32 | 4,230 | — | — |
| Other[6] | 26– 69 | [7]22,498 | 9 | 801 |
| Total | [8]3,714–[9]3,837 | 387,552 | 3,586 | 357,186 |

[e] Estimated. [p] Preliminary.

[1] Tonnage data suppressed by Bureau of Census effective Jan. 1, 1989; alternate sources as described. Reinstated Jan. 1, 1990, excluding U.S.S.R. Ranked in relative order of importance by country.

[2] Bureau of Census c.i.f. data, excluding Canadian value for 1989 (see footnote 3). Grand totals as reported by Bureau of Census.

[3] Canadian tonnage and value data for 1989 as published by Statistics Canada, courtesy Canadian Fertilizer Institute. Value of Canadian shipments converted to U.S. dollars.

[4] Canadian ammonia imports in 1989 valued at $151,706,746 c.i.f. by Bureau of Census.

[5] U.S. Bureau of Mines data.

[6] Fifteen countries; principally Colombia in 1990.

[7] Determined by difference; includes discrepancy between Canadian import value as reported by Bureau of Census (c.i.f.) and Statistics Canada (see footnotes 3 and 4).

[8] Sum of data reported by The Fertilizer Institute.

[9] Sum of data reported by U.S. Bureau of Mines.

Sources: Bureau of the Census, The Fertilizer Institute, U.S. Bureau of Mines, Canada (1989); Bureau of the Census and U.S. Bureau of Mines (1990).

Germany (Eastern states), and Romanian shipments that had previously been landed at prices below fair market value. A small shipment of U.S.S.R. urea reported by the Bureau of the Census in November was in error.

## World Review

Geopolitical events in Eastern Europe and the Persian Gulf dominated the global nitrogen fertilizer scene in 1990.

In Eastern Europe, the drive toward democratization was accompanied by sweeping political reforms that placed downward pressure on Eastern bloc economies. Fossil fuel energy essential to ammonia production was in short supply and portended significant shortfalls in nitrogen fertilizers critical to domestic consumption and trade. In early 1990, Romania declared force majeure on urea exports as did Poland and Hungary later in the year; shipments of ammonia and urea from the U.S.S.R. and other Eastern European nations were cut back. It is estimated that Eastern European ammonia supply capability declined by more than 2 million tons (5%) in 1990.

Iraq's invasion of Kuwait in early August played havoc with the export-oriented ammonia and urea fertilizer industries on the Persian Gulf. Iraq and Kuwait in combination represented about

TABLE 12

### U.S. EXPORTS AND IMPORTS OF MAJOR NITROGEN COMPOUNDS IN 1990

(Thousand short tons)

| Compound | Gross weight | Nitrogen content | Value[1] (thousands) |
|---|---|---|---|
| EXPORTS | | | |
| Fertilizer materials: | | | |
| Ammonium nitrate[2] | 46 | 15 | NA |
| Ammonium sulfate[2] | 1,123 | 236 | NA |
| Anhydrous ammonia | 646 | 531 | NA |
| Diammonium phosphate | 8,550 | 1,539 | NA |
| Monoammonium phosphate | 812 | 89 | NA |
| Nitrogen solutions | 514 | 154 | NA |
| Sodium nitrate | 5 | 1 | NA |
| Urea | 941 | 433 | NA |
| Mixed chemical fertilizers[3] | 215 | 34 | NA |
| Other ammonium phosphates[4] | 61 | 10 | NA |
| Other nitrogenous fertilizers[5] | 120 | 5 | NA |
| Total | 13,032 | 3,046 | NA |

See footnotes at end of table.

TABLE 12—Continued

### U.S. EXPORTS AND IMPORTS OF MAJOR NITROGEN COMPOUNDS IN 1990

(Thousand short tons)

| Compound | Gross weight | Nitrogen content | Value[1] (thousands) |
|---|---|---|---|
| EXPORTS—Continued | | | |
| Industrial chemicals: | | | |
| Ammonia, aqua (ammonia content) | 31 | 26 | $2,183 |
| Ammonium compounds[6] | 3 | 1 | 4,949 |
| Ammonium phosphate (ortho) | (7) | (7) | 82 |
| Potassium cyanide | 1 | (7) | 2,064 |
| Sodium cyanide | 7 | 2 | 61,270 |
| Other cyanides and cyanates | 1 | (7) | 4,893 |
| Hydrazine, hydroxylamine and related inorganic salts | 15 | 7 | 24,972 |
| Bismuth-silver nitrates | (7) | (7) | 9,939 |
| Potassium nitrate | 9 | 1 | 3,338 |
| Other nitrates | 4 | 1 | 6,350 |
| Nitric and/or sulfonitric acids | 14 | 2 | 3,980 |
| Nitrites | 4 | 1 | 2,637 |
| Total[8] | 89 | 41 | 126,658 |
| Grand total[8] | 13,122 | 3,087 | NA |
| IMPORTS | | | |
| Fertilizer materials: | | | |
| Ammonium nitrate[2] | 448 | 150 | $48,954 |
| Ammonium nitrate-limestone mixtures | 1 | (7) | 99 |
| Ammonium sulfate[2] | 398 | 84 | 34,403 |
| Anhydrous ammonia[9] | 3,586 | 2,947 | 357,186 |
| Calcium nitrate | [e]86 | [e]13 | 10,254 |
| Diammonium phosphate | 12 | 2 | 3,271 |
| Monoammonium phosphate | 56 | 6 | 13,467 |
| Nitrogen solutions | 443 | 133 | 31,429 |
| Potassium nitrate | 40 | 5 | 11,422 |
| Potassium nitrate-sodium nitrate mixtures | 53 | 8 | 6,277 |
| Sodium nitrate | 157 | 25 | 20,015 |
| Urea | 2,050 | 943 | 250,507 |
| Mixed chemical fertilizers[3] | 177 | 21 | 24,380 |
| Other ammonium phosphates[4] | 66 | 11 | 10,095 |
| Other nitrogenous fertilizers[5] | 146 | 27 | 25,544 |
| Total[8] | 7,719 | 4,375 | 847,304 |
| Industrial chemicals: | | | |
| Ammonia, aqua (ammonia content) | [e]15 | [e]5 | 601 |
| Ammonium compounds[6] | 16 | 4 | 21,825 |
| Calcium cyanamide | (7) | (7) | 267 |
| Potassium cyanide | 1 | (7) | 1,749 |
| Sodium cyanide | 14 | 4 | 18,544 |
| Other cyanides and cyanates[10] | 4 | 1 | 4,392 |
| Hydrazine, hydroxylamine and related salts | 4 | 2 | 6,644 |
| Bismuth and silver nitrates | (7) | (7) | 4,989 |

See footnotes at end of table.

1.5% of total world ammonia capacity and 2.5% of world urea capacity. In 1989, Iraq and Kuwait accounted for about 5% of total world urea and ammonia N trade. War would reportedly result in the damage and destruction of nitrogen production facilities in both Iraq and Kuwait that could require approximately 5 to 6 years to repair and replace.

The outbreak of War in the Persian Gulf could cut off or throttle back nitrogen fertilizer production in Bahrain, Qatar, Saudi Arabia, and the United Arab Emirates, resulting in the potential loss of up to another 10% of world N trade in the form of ammonia and urea. In 1990, it was estimated that ammonia production in the Mideast would decline by a net of 400,000 tons (8%) because of the Persian Gulf crisis.

***Industry Structure.***—Approximately 108 million short tons of anhydrous ammonia N was produced in 66 countries during 1990, of which about 11 million tons N (10%) was directly traded. Ammonia was converted into about 39 million tons of urea N in 55 countries, of which about 10 million tons (26%) was traded. Total world nitrogen fertilizer consumption was about 87 million tons N, of which trade accounted for about 22 million tons N (25%).

Global ammonia was produced in the developed and developing countries that have access to fossil fuel feedstocks, principally natural gas, naptha, petroleum refinery offgases and condensates, and coal and coke gases. The supply pattern, in general, followed the world population trend, with Asia and Eastern Europe—including the U.S.S.R.—accounting for more than 60% of the global ammonia supply. The developed regions—North America (United States and Canada), Western Europe, and Oceania—produced ammonia primarily for domestic use and accounted for about 25% of the world total. The energy-rich countries of the Middle East accounted for about 5% of the world supply and exported significant quantities of ammonia and urea to the global community.

***Capacity.***—The data in table 14 are rated capacity for ammonia plants as of December 31, 1990. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given

TABLE 12—Continued

## U.S. EXPORTS AND IMPORTS OF MAJOR NITROGEN COMPOUNDS IN 1990

(Thousand short tons)

| Compound | Gross weight | Nitrogen content | Value[1] (thousands) |
|---|---|---|---|
| IMPORTS—Continued | | | |
| Industrial chemicals—Continued | | | |
| Strontium and/or other nitrates | 3 | (7) | 3,071 |
| Nitric and/or sulfonitric acids | 11 | 2 | 1,753 |
| Sodium and other nitrites | 4 | 1 | 2,017 |
| Total[8] | 71 | 19 | 65,852 |
| Grand total[8] | 7,791 | 4,395 | 913,156 |

[e] Estimated. NA Not available.

[1] Export values f.o.b.; import values c.i.f.

[2] Includes industrial chemical products.

[3] Harmonized codes 3105.10.0000 and 3105.20.0000.

[4] Codes 3105.51.0000, 3105.59.00 (exports and imports); 3102.70.0000 (exports); 3105.40.0050 (imports).

[5] Codes 3101.00.0000, 3102.29.0000, 3102.60.0000, 3102.90.0000 (exports and imports); and 3105.90.0050 (imports).

[6] Carbonates, chloride, fluorides, and tungstate (exports and imports); bromide, molybdate, orthophosphate, and perrhenate (imports).

[7] Less than 1/2 unit.

[8] Data may not add to totals shown because of independent rounding.

[9] Anhydrous ammonia tonnage data as reported by U.S. Bureau of Mines in 1989 and for U.S.S.R. in 1990; includes industrial ammonia. Value data, Bureau of Census.

[10] Data for code 2837.19.0020 (other cyanides) deleted or omitted by Bureau of Census. In 1989, 6,000 tons valued at $5.7 million was reported.

Source: Bureau of the Census. Effective Jan. 1, 1989, U.S. exports and imports were reported under the new international Harmonized Commodity Description and Coding System (Harmonized System).

acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure.

In 1990, about 2 million annual tons of new ammonia capacity was brought on-stream, and about 1 million annual tons was permanently closed. Another 5.5 million annual tons was under construction and scheduled to come on-stream during 1991 and 1992.

The major ammonia capacity that was scheduled on-stream during 1990-92 was as follows: China—1.8 million annual tons in Sichuan, Henan, and Liaoning Provinces, together with small plants at various locations; U.S.S.R.—1.5 million annual tons in the Ukraine and at various locations; India—0.8 million annual tons in Kakinada and Rajasthan; Belgium—0.7 million annual tons at Antwerp; Bangladesh—0.5 million annual tons at Jamalpur and Ghorasal; Egypt—0.5 million tons at Suez and Abu Qir; Indonesia—0.5 million tons at Sumatra; and Turkey—0.4 million annual tons at Gemlik.

### Current Research

M. W. Kellogg of Houston, TX, announced two major advances in its ammonia process technology: the Kellogg Reforming Exchanger System (KRES) and the Kellogg Advanced Ammonia Process (KAAP), a joint technology development with British Petroleum.

Kellogg's KRES design was revolutionary in that it completely eliminated the conventional fired primary reformer from the ammonia production process. KRES is environmentally attractive because without a primary reformer, nitrogen oxide emissions are substantially reduced. The system could be easily installed in new or existing plants and would save up to 10% on capital costs.

The KAAP process employs a novel ammonia synthesis catalyst that was claimed to be the first significant breakthrough in catalyst technology since 1927. The proprietary KAAP catalyst is up to 20% more active than conventional iron catalysts. The KAAP system was to be employed in a retrofit project designed to increase production capability by 40% at Ocelot's ammonia plant in Kitimat, British Columbia.

In late 1990, the Department of Agriculture (USDA) and the Department of Energy (DOE) signed a "memorandum of understanding" for accelerating the development of ethanol and other alternative fuels and fuel additives from agricultural and forestry products.[18] The agreement promised significant new markets for U.S. farmers and supported the President's National Energy Strategy that focused on a reduction in foreign energy dependency and a cleaner environment.

Research and development activities were to focus on four key areas related to production of fuels from agricultural and forestry products: (1) improving the conversion efficiency of biomass products to fuel products, (2) assessing economic effects of alternative fuel production, (3) assessing environmental effects of production and use of alternative fuels, and (4) enhancing economic competitiveness of such fuels.

Exxon Research and Engineering Co. of Florham Park, NJ, developed the THERMAL DeNox Process that significantly reduced NOx emissions by injecting ammonia into flue gas streams emanating from stationary combustion sources. THERMAL DeNOx is a noncatalytic process for NOx reduction based on the gas phase homogeneous reaction between NOx in flue gas and ammonia that produces nitrogen and water. The patented process was offered for license by Exxon Research and Engineering Co.[19]

The Electric Power Research Institute in Palo Alto, CA, developed NOxOUT proprietary technology that injected urea and other commodity chemicals into coal-fired boilers to reduce NOx emissions. Nalco Chemical of Naperville, IL, and Fuel-Tech of Stamford, CT, formed a joint-venture firm NalcoFuel-Tech to market NOxOUT technology.[20]

## OUTLOOK

Global ammonia operating rates declined in 1990 owing to a significant downturn in Eastern bloc demand and supply disruptions precipitated by the Persian Gulf crisis. Per capita nitrogen consumption dropped below 41 pounds for the first time since the dismal global agricultural crisis of 1986.

The data of table 15 suggest that soft market conditions will prevail between 1990 and 1994, principally because of significant new additions to world capacity

TABLE 13

## WORLD ANHYDROUS AMMONIA ANNUAL PRODUCTION CAPACITY, DECEMBER 31, 1990

(Thousand short tons per year of ammonia)

| | Rated capacity[1] |
|---|---|
| North America: | |
| Canada | [r]4,000 |
| United States | [r]17,406 |
| Total[2] | [r]21,410 |
| Latin America: | |
| Argentina | [r]120 |
| Brazil | [r]1,370 |
| Colombia | [r]180 |
| Cuba | 440 |
| Mexico | 3,290 |
| Peru | 180 |
| Trinidad and Tobago | 1,950 |
| Venezuela | 900 |
| Total[2] | [r]8,430 |
| Western Europe: | |
| Austria | 570 |
| Belgium | 530 |
| Finland | 90 |
| France | 2,470 |
| Germany, Federal Republic of: | |
| Eastern states | 2,070 |
| Western states | 2,450 |
| Greece | 470 |
| Iceland | 10 |
| Ireland | 510 |
| Italy | [r]1,950 |
| Netherlands | 4,250 |
| Norway | 610 |
| Portugal | [r]340 |
| Spain | [r]1,010 |
| Switzerland | 60 |
| United Kingdom | [r]1,900 |
| Total | [r]19,290 |
| Eastern Europe: | |
| Albania | 100 |
| Bulgaria | 1,830 |
| Czechoslovakia | [r]1,100 |
| Hungary | 1,090 |
| Poland | 3,020 |
| Romania | 5,120 |
| U.S.S.R. | [r]34,450 |
| Yugoslavia | 1,630 |
| Total | [r]48,340 |
| Africa: | |
| Algeria | 1,130 |
| Egypt | [r]1,230 |
| Libya | 380 |
| Nigeria | 380 |
| South Africa, Republic of | 830 |
| Zambia | 60 |
| Zimbabwe | 70 |
| Total | [r]4,080 |
| Asia: | |
| Afghanistan | 80 |
| Bangladesh | 1,100 |
| Burma | 280 |
| China | [r]25,970 |
| India | 11,630 |
| Indonesia | 3,840 |
| Japan | [r]2,260 |
| Korea, North | 1,200 |
| Korea, Republic of | [r]950 |
| Malaysia | 380 |
| Pakistan | 1,680 |
| Taiwan | 340 |
| Vietnam | 70 |
| Total | [r]49,780 |
| Middle East: | |
| Abu Dhabi | 380 |
| Bahrain | 450 |
| Iran | [r]1,250 |
| Iraq | 810 |
| Israel | 90 |
| Kuwait | 1,120 |
| Qatar | 670 |
| Saudi Arabia | 1,170 |
| Syria | 380 |
| Turkey | [r]920 |
| Total | [r]7,240 |
| Oceania: | |
| Australia | [r]750 |
| New Zealand | 100 |
| Total | [r]850 |
| Total world | [r]159,420 |

[r] Revised.

[1] Includes capacity at operating plants as well as plants on standby basis. Rated capacity based on 340-day-per-year effective operation.

[2] Data do not add to total shown because of independent rounding.

Sources: Branch of Industrial Minerals, U.S. Bureau of Mines, and International Fertilizer Industry Association Ltd. (IFA).

and a protracted period of economic recovery in the Eastern bloc. A renewal of hostilities in the Persian Gulf would again negatively impact ammonia and urea trade and could stress the global economy through the mechanism of yet another oil shock. By 1995, there appears to be a reasonably favorable probability that ammonia supply and demand will return to balance.

The U.S. Bureau of Mines ammonia nitrogen demand forecast was developed from world population projections of the United Nations, together with historic per capita consumption trends, taking into consideration geopolitical factors in Eastern Europe and the Mideast. Steady-state conditions were assumed for weather. World ammonia capacity projections were provided by the International Fertilizer Industry Association Ltd., Paris, France.

Turning to the U.S. outlook, a continuation of favorable trends in the nitrogen fertilizer and agricultural sectors would appear to be a distinct possibility. U.S. ammonia capacity expansion plans are minimal, and agronomic fundamentals that were improved by the 1985 farm bill should be further perpetuated by the new 1990 farm bill.

The mechanisms of the new ECARP, together with regular program acreage reductions, should hold U.S. crop acreage at about the current 330 million acres. This, together with the Export Enhancement Initiative, should control crop inventories and provide favorable crop prices for the U.S. farmer.

Issues critical to a favorable U.S. nitrogen fertilizer scenario include (1) a continuation of reasonably priced natural gas for U.S. ammonia production, (2) new industrial outlets for U.S. corn-based ethanol in reformulated motor fuels under the provisions of the Clean Air Act of 1990, (3) new markets for the Saferco ammonia and urea nitrogen complex under construction in Sasketchewan that would not result in the significant closure of U.S. nitrogen capacity, (4) a favorable resolution of the ongoing Uruguay round of General Agreement of Tariffs and Trade negotiations that would liberalize global agricultural trade and provide the United States with freerer access to global markets, (5) favorable U.S. implications for the proposed Free-Trade Agreement with Mexico and for the proposed granting of most favored nation (MFN) status to the U.S.S.R. and other Eastern European countries, (6) a smooth transition in democratic reforms in Eastern Europe, and (7) resolution of the MFN status debate with China.

TABLE 14

## AMMONIA: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand short tons of contained nitrogen)

| Country | 1986 | 1987 | 1988 | 1989 | 1990[e] |
|---|---|---|---|---|---|
| Afghanistan[e] | 44 | 44 | 44 | 44 | 44 |
| Albania[e] | [r]100 | [r]105 | [r]110 | [r]120 | 110 |
| Algeria | [e]165 | 192 | 217 | 145 | 150 |
| Argentina | 69 | 79 | 86 | 82 | [2]77 |
| Australia | 375 | 456 | 425 | [r]379 | [2]425 |
| Austria | [e]495 | [e]495 | [r]450 | [r]452 | 452 |
| Bahrain | 318 | 304 | 340 | [r]327 | [2]352 |
| Bangladesh | 430 | 480 | 742 | [r]854 | 870 |
| Belgium | 337 | 296 | 402 | [r]322 | 330 |
| Brazil | 972 | 1,049 | 1,031 | 1,079 | [2]1,034 |
| Bulgaria | 1,203 | 1,180 | [r]1,480 | [r][e]1,430 | 1,320 |
| Burma | 147 | 130 | [r]136 | [r]108 | [2]86 |
| Canada | 3,208 | 3,182 | [r]3,626 | [r]3,681 | [2]3,267 |
| China[e] | 17,100 | 16,000 | 17,900 | 18,700 | 19,800 |
| Colombia | 103 | 98 | 93 | 101 | [2]108 |
| Cuba | 180 | 164 | 149 | [r]147 | 165 |
| Czechoslovakia | 838 | 855 | 850 | [r]878 | [2]874 |
| Egypt | [r]748 | [r]870 | [r]869 | [r]802 | 810 |
| Finland | 74 | 55 | 47 | [r]46 | [2]26 |
| France | 2,229 | 2,237 | [e]2,020 | [e]1,630 | [2]1,748 |
| Germany, Federal Republic of: | | | | | |
| Eastern states | 1,315 | 1,296 | 1,274 | [e]1,270 | 1,100 |
| Western states | 1,731 | 2,129 | [r]2,011 | [r]1,928 | [2]1,801 |
| Greece | 266 | 280 | 290 | [r]267 | [2]283 |
| Hungary | 840 | 867 | [r]763 | [r]742 | 570 |
| Iceland | 9 | 10 | 10 | [e]9 | 9 |
| India[3] | 5,438 | 5,842 | 6,840 | [r]7,342 | [2]7,741 |
| Indonesia | 2,534 | 2,606 | 2,609 | 2,785 | 2,900 |
| Iran | 73 | 131 | 160 | 370 | [2]463 |
| Iraq[e] | 66 | 66 | 345 | [2]522 | 440 |
| Ireland | 391 | 440 | 460 | [r]425 | 435 |
| Israel | 63 | 68 | 63 | [r] [e]63 | 63 |
| Italy | 1,712 | 1,582 | [r]1,721 | 1,594 | 1,320 |
| Japan | 1,662 | 1,715 | 1,680 | [r]1,696 | [2]1,688 |
| Korea, North[e] | 500 | 500 | [r]550 | [r]550 | 550 |
| Korea, Republic of | 470 | 523 | 558 | 529 | 500 |
| Kuwait | 497 | 637 | 530 | 733 | [2]322 |
| Libya | 388 | 386 | [r]239 | [r]234 | 234 |
| Malaysia | 276 | 354 | 331 | 307 | [2]252 |
| Mexico | 1,766 | 1,922 | 2,279 | [r]2,315 | [2]2,385 |
| Netherlands | [r]2,409 | [r]2,521 | 3,258 | 3,308 | 3,490 |
| New Zealand | 80 | 80 | 80 | [r]77 | [2]77 |
| Nigeria | — | 142 | 342 | [r]330 | [2]367 |
| Norway | 330 | 383 | 467 | 421 | [2]475 |
| Pakistan | 1,273 | 1,300 | [r]1,293 | [r][e]1,295 | 1,300 |
| Peru[e] | 110 | 88 | 105 | [r]65 | 65 |
| Poland | 2,341 | 2,400 | [r]2,577 | [r][e]2,535 | 2,150 |
| Portugal | 130 | 171 | 210 | [r]167 | [2]218 |

See footnotes at end of table.

TABLE 14—Continued

## AMMONIA: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand short tons of contained nitrogen)

| Country | 1986 | 1987 | 1988 | 1989 | 1990[e] |
|---|---|---|---|---|---|
| Qatar | 600 | 618 | 657 | [r]647 | [2]639 |
| Romania | 3,352 | 3,073 | [e]3,090 | [e]2,870 | 2,100 |
| Saudi Arabia | 514 | 702 | 956 | [r]952 | [2]1,039 |
| Somalia[e] | 17 | 8 | — | — | — |
| South Africa, Republic of | [e]640 | [r]603 | 520 | 502 | [2]503 |
| Spain | 512 | 495 | 525 | 608 | [2]533 |
| Sweden | 51 | 37 | — | — | — |
| Switzerland[e] | 33 | 43 | [r]35 | [r]35 | 35 |
| Syria | 151 | 102 | 87 | 135 | [2]114 |
| Taiwan | 292 | 268 | 307 | [r]245 | 240 |
| Trinidad and Tobago | 1,258 | 1,243 | 1,528 | [e]1,700 | [2]1,676 |
| Turkey | [r]210 | [r]364 | [r e]340 | [r e]340 | 445 |
| U.S.S.R. | 21,605 | 22,050 | [r]22,270 | [r]21,495 | 20,400 |
| United Arab Emirates | 321 | [r]343 | 330 | 357 | [2]322 |
| United Kingdom | 1,530 | 1,560 | 1,218 | 1,143 | 1,270 |
| United States[4] | 11,909 | 13,232 | 13,827 | [r]13,449 | [2]13,940 |
| Venezuela | [r]571 | [r]578 | [r]621 | [r]587 | [2]691 |
| Vietnam | 40 | 40 | 40 | [e]40 | 40 |
| Yugoslavia | 897 | 1,033 | 946 | 750 | 740 |
| Zambia | 27 | 37 | 18 | [r]13 | [2]7 |
| Zimbabwe | 54 | 59 | 71 | 68 | [2]76 |
| Total | [r]100,389 | [r]103,198 | [r]109,448 | [r]109,142 | 108,056 |

[e]Estimated. [r]Revised.

[1]Table includes data available through May 31, 1991.

[2]Reported figure.

[3]Data are for years beginning Apr. 1 of that stated.

[4]Synthetic anhydrous ammonia; excludes coke oven byproduct ammonia.

TABLE 15

## WORLD ANHYDROUS AMMONIA SUPPLY-DEMND RELATIONSHIPS[1]

(Million short tons nitrogen)

| | 1985 | 1986 | 1987 | 1988 | 1989 | 1990[e p] | 1991[2] | 1992[2] | 1993[2] | 1994[2] | 1995[2] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Capacity[3] | 122.9 | 125.8 | 126.4 | 129.9 | 131.4 | 132.2 | 134.6 | 136.7 | 140.1 | 142.0 | 143.5 |
| Demand:[4] | | | | | | | | | | | |
| Fertilizer[r] | 88.7 | 89.2 | 91.7 | 97.8 | 97.4 | 96.4 | 97.8 | 100.5 | 103.2 | 105.8 | 108.5 |
| Industrial[r] | 11.6 | 11.2 | 11.5 | 11.6 | 11.7 | 11.7 | 11.8 | 12.0 | 12.2 | 12.5 | 12.7 |
| Total[r] | 100.3 | 100.4 | 103.2 | 109.4 | 109.1 | 108.1 | 109.6 | 112.5 | 115.4 | 118.3 | 121.2 |
| Operating rate[5] | 82% | 80% | 82% | 84% | 83% | 82% | 81% | 82% | 82% | 83% | 84% |
| Consumption:[r] | | | | | | | | | | | |
| Pounds per capita[6] | 41.8 | 41.0 | 41.3 | 42.9 | 42.0 | 40.8 | 40.6 | 40.9 | 41.2 | 41.5 | 41.8 |
| Population: | | | | | | | | | | | |
| Billion[7] | 4.8 | 4.9 | 5.0 | 5.1 | 5.2 | 5.3 | 5.4 | 5.5 | 5.6 | 5.7 | 5.8 |

[e]Estimated. [p]Preliminary. [r]Revised.

[1]Calendar years.

[2]Forecast.

[3]Design capacity, 340-day-per-year effective operation.

[4]Ammonia consumed in the production of fertilizer and industrial products, including process losses.

[5]Total demand as a percentage of design capacity.

[6]Ammonia demand expressed in pounds per person.

[7]Statistical Abstract of the United States 1990; Bureau of the Census.

Source: U.S. Bureau of Mines. Division of Mineral Commodities, Branch of Industrial Minerals.

---

[1] Chemical Business. Nitrogen—An Element Whose Time Has Come Again. V. 13, No. 3, Mar. 1991, p. 9.

[2] Sittig, M. Nitrogen in Industry. Van Nostrand Reinhold, 1965, p. 5.

[3] Iowa Department of Agriculture. Anhydrous Ammonia Safety. Feb. 1991, 58 pp.

[4] Fertilizer Focus. New Way Ahead for SQM. V. 8, No. 4, Middlesex, England, May 1991, pp. 67–70.

[5] U.S. President. Presidential documents, v. 26, No. 48, Dec. 3, 1990. Office of the Federal Register, Washington, DC, 1990, pp. 1926–1928.

[6] ———. Presidential documents, v. 26, No. 45, Nov. 12, 1990. Office of the Federal Register, Washington, DC, 1990, pp. 1764–1766.

[7] ———. Presidential documents, v. 26, No. 46, Nov. 19, 1990. Office of the Federal Register, Washington, DC, 1990, pp. 1824–1826.

[8] U.S. Department of Energy. National Energy Strategy, Powerful Ideas for America. First ed. Washington, DC, Feb. 1991, 267 pp.

[9] Pages 144-170 of work cited in footnote 8.

[10] Haigwood, B. North American Markets for Alcohol and Alcohol-Derived Motor Fuels and Need for Tax Incentives. Information Resources, Washington, DC. Paper in Energy From Biomass and Wastes XV Conference cosponsored by U.S. Dep. Energy and Energy Mines and Resour. Canada, Inst. Gas Tech. Programs, Washington, DC, Mar. 28, 1991, 20 pp.

[11] Federal Register. Department of Commerce, Bureau of the Census. Current Industrial Reports, Notice of Determination. V. 55, No. 235, Dec. 6, 1990, p. 50339.

[12] Securities and Exchange Commission. Freeport-McMoRan Resource Partners, Ltd. Partnership, Form 10-K Report, fiscal year ended Dec. 31, 1990, p. 2.

[13] Work cited in footnote 12.

[14] Cargill Fertilizer. Fertilizer Applications. V. 6, No. 1, Spring 1991, 7 pp.

[15] Stacklin, C. (Fluor Daniel, Inc., Irvine, CA) Private communication, Apr. 1991.

[16] Federal Register. U.S. Department of Transportation, Research and Special Programs Administration. Criteria for Poisonous Gases; Final Rules and Regulations. V. 55, No. 246, Dec. 21, 1990, p. 52434.

[17] Mapco Ammonia Pipeline, Inc. Green Markets Ammonia Conference, Scottsdale, AZ, Oct. 29, 1990, 8 pp.

[18] U.S. Department of Agriculture. USDA, DOE to Collaborate on Alternative Fuels Research and Development. Office of Public Affairs, Mar. 1, 1991.

[19] THERMAL DeNOx Process, (technical literature) Exxon Research and Engineering Co., Florham Park, NJ 07932.

[20] Chemical Week. NOx Emisssion Control Venture. Dec. 13, 1989, p.19.

## OTHER SOURCES OF INFORMATION

AgReport, Resource Washington, Inc., Washington, DC, 20005, monthly and special.

Ammonia Plant Safety, American Institute of Chemical Engineers, annual.

Blue, Johnson & Associates, agricultural consultants, Menlo Park, CA 94026.

Canadian Fertilizer Institute, Ottawa, Ontario, Canada.

Chemical Business, Schnell Publishing Co., monthly.

Doane Information Services, agricultural consultants, St. Louis, MO.

Ericksen, G. E. Geology and Origin of the Chilean Nitrate Deposits. U.S. Geol. Surv. Professional Paper 1188, 1981, 37 pp.

The Douglas Update, Douglas Associates, Florence, AL 35630, monthly.

Finds, Stokes Engineering Co., Weston, CT 06883, quarterly.

Green Markets, McGraw-Hill Inc., Fertilizer Intelligence Weekly.

Nitrogen, The British Sulphur Corp. Ltd. (London).

Nelson, L. B. History of the U.S. Fertilizer Industry. Tennessee Valley Authority, 1990, 522 pp.

Office of Technology Assessment, Congress of the United States, Washington, DC.

The Fertilizer Institute, Washington, DC 20002.

The Scotts Co., Scotts Fertilizers, Marysville, OH 43041

Union Carbide Industrial Gases Inc., Linde Div., Danbury, CT 06817

U.S. Department of Agriculture, Economic Research Service, Washington, DC.

☆ U.S. Government Printing Office : 1991 - 281-983/40099

BLM Library
Denver Federal Center
Bldg. 50, OC-521
P.O. Box 25047
Denver, CO 80225